Accuracy and Precision of a System for Assessing Severity of Tooth Wear

Tadasu Haketa, DDS, PhD[a]/Kazuyoshi Baba, DDS, PhD[b]/Satoshi Akishige, DDS, PhD[c]/Kenji Fueki, DDS, PhD[d]/Koji Kino, DDS, PhD[e]/Takashi Ohyama, DDS, PhD[f]

Purpose: The purpose of this study was to introduce a computer-assisted quantitative tooth wear–analyzing system and test its accuracy and precision. ***Materials and Methods:*** An image of a horizontally projected dental arch was captured, and the facet area of each tooth was calculated using a digital image analyzer. For normalization, the facet area of the individual tooth was divided by the total area of the corresponding tooth; this result was the tooth wear score. The accuracy and precision of this method were determined through the intraclass correlation coefficient using 10 dental casts. Tooth wear on the dental casts of 50 subjects was actually measured. ***Results:*** The accuracy of the tooth wear score determined by a newly trained examiner was greater than 0.85 of the intraclass correlation coefficient; this was tested against the score determined by consensus of three experienced examiners. The reproducibility within a 1-week interval was also greater than 0.85. With regard to the tooth wear score from 50 sets of dental casts, the distribution of tooth wear was generally consistent with data reported in the literature. ***Conclusion:*** The results suggest that the newly trained examiner can exhibit adequate accuracy and precision after appropriate training in identifying tooth wear facets. Recorded data from 50 subjects added face validity to this new system. *Int J Prosthodont 2004;17:581–584.*

Many factors are associated with the incisal or occlusal breakdown of teeth. For example, age is definitely associated with the level of a tooth's breakdown; therefore, the measurement of tooth wear has been applied in anthropologic studies on age determinations.[1,2] Other than age, the effects of parafunction,[3–6] composition of saliva,[3] and industrial environment[7–9] on tooth wear have also been investigated in the literature. However, in any individual case, the multifactorial causes of dental wear make it difficult to determine the etiologic factors responsible for the wear.

Proof of any relationship between tooth wear and potential etiologic factors requires reliable and accurate measurement. Several systems for classification and measurement of tooth wear have been reported. The commonly used clinical examination–based systems[3,8,10–17] require clinicians to examine and score the severity of wear in the mouth or on a cast with a categoric scale. Using these systems, the level of reliability varies depending on the examiner's ability, and the reported reproducibility varies greatly.[18]

For a more precise and detailed study, tooth wear may be evaluated with advanced methods, such as the actual measurement of the tooth's cusp height,[19] image analyses,[20,21] scanning electron microscopy,[22] or computer graphics by using profilometry.[23–25] These systems are not easy to handle and require laboratory-based measurements on dental casts; however, they allow better understanding of tooth wear for research purposes. Even with these semiautomatic systems,

[a]*Assistant Professor, TMJ Clinic, Tokyo Medical and Dental University.*
[b]*Lecturer, Removable Prosthodontics, Graduate School, Tokyo Medical and Dental University.*
[c]*Private Practice, Tokyo.*
[d]*Assistant Professor, Removable Prosthodontics, Graduate School, Tokyo Medical and Dental University.*
[e]*Associate Professor, TMJ Clinic, Tokyo Medical and Dental University.*
[f]*Professor and Chair, Removable Prosthodontics, Graduate School, Tokyo Medical and Dental University.*

Correspondence to: *Dr Tadasu Haketa, TMJ Clinic, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-Ku, Tokyo 113-8549, Japan. Fax: + 81-3-5803-5713. e-mail: th.tmj@tmd.ac.jp*

Fig 1 Marked facets of a maxillary cast prepared for measurement using digital image analyzer.

Fig 2 CCD camera, digital image analyzer, and PC used for measurement.

subjective identification of wear facets by the examiner is unavoidable. Acquired data still depend on the examiner's ability to identify the area of tooth wear facets on dental casts. To the best of the authors' knowledge, there have been no reports about testing the wear facet identification procedure for accuracy and precision.

Considering the methodologic limitations of tooth wear measurement, the purpose of this study was to introduce a computer-based system for assessing severity of tooth wear and evaluate its accuracy and precision.

Materials and Methods

Subjects

Fifty-six students (27 men and 29 women, mean age 24.3 ± 2.4 years) from Tokyo Medical and Dental University were selected, and 50 of them volunteered to participate in this research project after informed consent was obtained. To be selected as a study subject, an individual had to have been: *(1)* in good health, and *(2)* between the ages of 22 and 32 years. Exclusion criteria were: *(1)* more than two missing teeth per quadrant (excluding third molars), *(2)* use of any prescription medication or daily alcohol, *(3)* ongoing dental or physical therapy, and *(4)* compromised mental or physical ability.

Tooth Wear Measurement System

Impressions of maxillary and mandibular dental arches were made using addition-cured silicone impression material (Exafine, GC), and dental casts were made of super-hard dental stone (Fujirock, GC). The edges of the wear facets on each tooth were outlined with a sharp pencil by examiners, and these facets were shaded with black ink (Fig 1). Teeth restored by a complete cast crown or onlays were excluded from the analysis.

A charge-coupled device (CCD) camera–based digital image analyzer (Luzex-FS, Nireco) (Fig 2) was used to measure the areas of the wear facets on the dental casts. A dental cast was set on the measuring table with its occlusal plane perpendicular to the axis of the camera. A two-dimensional image of the arch was captured, and the area of the marked wear facet was measured for each tooth using automatic software.

Because the size of each tooth differs, the wear facet area was normalized for between-teeth comparisons. First, five sets of dental casts were randomly selected from 50 dental cast sets, and the total occlusal area of each tooth was measured. The total occlusal area for each tooth was considered the greatest extent of the tooth as captured by the camera. The total occlusal area for each tooth was averaged; then, the wear facet area of each individual tooth was divided by the averaged total occlusal area of the corresponding tooth to obtain the tooth wear score. This score ranged from a minimum of 0 (no tooth wear) to a maximum of 1.0 (completely worn occlusal surface).

Accuracy and Precision of Tooth Wear Score

The accuracy and precision of the wear facet identification method were determined using another 10 dental casts as follows. First, three experienced examiners identified every tooth on these dental casts and outlined the wear facet area; differences in identifying the facet were resolved by consensus. They then measured each marked facet area, calculated each tooth wear score, and finally found the mean tooth wear score of the entire arch for each of the 10 casts. This mean was used as the stan-

dard score, against which a newly trained examiner was calibrated for accuracy. Training and calibration taught the new examiner how to carefully outline the edges of the wear facets on each tooth. This training was performed on three different sets of casts before calibration testing was given. The new examiner was tested by using duplicates of the 10 above-mentioned casts. The examiner was judged to be fully trained when the intraclass correlation coefficient (ICC) between the examiner's scores and the standard scores of the 10 casts were above 0.80. After successfully passing the calibration, the examiner had to rescore the previously described 10 casts after an interval of 1 week and calculate the mean tooth wear score of each cast. The first and second mean tooth wear scores were compared to the standard score by using ICC to test the accuracy and precision of the new examiner's wear facet identification ability.

Measurement of Tooth Wear Score in 50 Subjects

Fifty maxillary and mandibular dental casts of 50 subjects were fabricated, and quantitative analyses of tooth wear facets were conducted using the method described above. The tooth wear score of each tooth and the mean tooth wear score for the maxillary and mandibular arches were calculated for 100 dental casts. Tooth wear scores were calculated for the central incisor, lateral incisor, canine, first premolar, second premolar, first molar, and second molar in the maxillary and mandibular arches, respectively. The Scheffé multiple comparison test was used to compare the tooth wear score among seven types of teeth in the maxilla and mandible, respectively. Each test guaranteed the significance at a 5% level for each comparison.

Results

The newly trained examiner passed the test on the first attempt, with an ICC of 0.91; therefore, these data served as the first session data. Regarding the accuracy of the examiner after 1 week, the ICC against the standard score was 0.87 (Table 1). Intraexaminer reproducibility, as measured by the ICC between the first and second sessions was 0.85. These scores were considered sufficient.[26]

The tooth wear score of each tooth was averaged for 50 subjects (Fig 3). In the maxillary arch, the three anterior teeth and the first molar exhibited significantly higher tooth wear scores than the second premolar (Scheffé multiple comparison, $P < .05$). In the mandibular arch, the central incisor exhibited a significantly higher tooth wear score than other teeth, and the second premolar exhibited a significantly lower score than the three anterior teeth and the first molar (Scheffé multiple comparison, $P < .05$).

Table 1 Intraclass Correlation Coefficient (ICC) as the Examiner's Accuracy and Reproducibility

Combination	ICC*
Standard score–first session	0.91 (0.87–0.94)
Standard score–second session	0.87 (0.81–0.92)
First session–second session	0.85 (0.76–0.89)

*Confidence intervals are in parentheses.

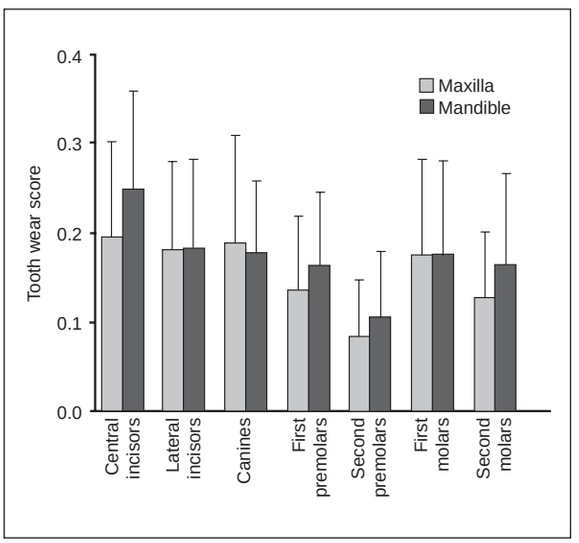

Fig 3 Mean tooth wear score of 50 subjects for each tooth.

Discussion

As mentioned above, the subjective identification of the wear facet, a potential source of measurement bias because of the examiner's variability, is inevitable, although the computer-assisted digital imaging method has a significant advantage over clinical examination–based methods for assessing the severity of tooth wear. To the best of our knowledge, when we began this study, there were several examination-based tooth wear measurement systems that evaluated the precision of the examiners[12,17,18,27]; however, no computer-based tooth wear measurement system has been tested.

We have obtained two conclusions from this study. First, the study data confirmed that a newly trained examiner may have an excellent ability to achieve a precise score using the method described in this report. The overall degree of intrarater reliability resulted in a score of 0.85. Second, excellent agreement with the standard score (0.91 and 0.87) can also be achieved. These data are unique because no prior research on the tooth wear

scoring method has presented standards for calibration of examiners, described the training procedures, or given minimum calibration performance criteria. Such information is essential if we wish to collect accurate research data on tooth wear with a scoring method. After the training procedures described in this study, a single examiner can score tooth wear accurately and precisely.

Regarding the standard score developed for use in this study, the consensus-based score among experts is a good way to establish a global score of tooth wear. However, this method may not be useful for research when the number of casts to be scored is extensive, data collection is ongoing over a long period, or tooth-by-tooth scoring of wear is required.

As far as the tooth wear score created in this study is concerned, it allows a between-teeth comparison of the severity of tooth wear within a subject. It also allows a between-subjects comparison, since the score is the ratio of the wear facet area to the premeasured total area of the corresponding tooth, not the actual quantity of the facet area. These aspects of our system are considered more useful than other systems for dealing with tooth wear severity.

It should be noted that the 2-D projected facet area on the horizontal plane may depend on the inclinations of each wear facet; therefore, our system may be considered less accurate than a 3-D system.[23–25] However, a study that compared the 2-D data with the actual surface area data revealed that the errors of 2-D measurements were consistently lower than 3% ± 1%, which was considered acceptable.[21]

With regard to the data from 50 subjects, in the maxillary arch, the anterior teeth and the first molar had high tooth wear scores; in the mandibular arch, the central incisors exhibited high tooth wear scores. The second premolar exhibited lower scores in both arches. Although these findings are not consistent with those obtained in studies using categoric scales,[4,10,11] they are in general agreement with studies using quantitative analysis with computer-assisted image-analyzing systems.[20] It should be noted that our results could not be fully generalized to our target population because the subjects were not a probability-based sample. Given this notation, these study results also add face validity to our method as a way of measuring tooth wear.

The accuracy and precision of our system for assessing severity of tooth wear by means of a computer-assisted digital image analyzer are high.

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